International Journal of Innovative Computing, Information and Control
Volume **6**, Number **9**, September **2010**

ICIC International ©2010 ISSN 1349-4198
pp. 3989–4000

STOCHASTIC STABILITY ANALYSIS AND SYNTHESIS FOR NONLINEAR FAULT TOLERANT CONTROL SYSTEMS BASED ON THE T-S FUZZY MODEL

Huaining Wu and Mingzhen Bai

School of Automation Science and Electrical Engineering
Beihang University (Beijing University of Aeronautics and Astronautics)
Beijing 100191, P. R. China
whn@buaa.edu.cn

Received March 2009; revised July 2009

Abstract. *This paper investigates the problem of stochastic stability analysis and synthesis for nonlinear active fault tolerant control systems (AFTCSs) based on the Takagi and Sugeno (T-S) fuzzy model and the parallel distributed compensation (PDC) scheme. Two random processes with Markovian transition characteristics are introduced to model the system component failure process and the fault detection and isolation (FDI) decision process, respectively. The random behavior of the FDI process is conditioned on the failure process state. Firstly, the exact-fuzzy-model-based case is considered, where the nonlinear AFTCS can be exactly represented by a T-S fuzzy model. Based on a stochastic Lyapunov function, a stochastic stability condition of the fuzzy system is derived in the form of linear matrix inequalities (LMIs). An LMI approach to the design of FDI-driven PDC controllers is also developed. Secondly, the uncertain-fuzzy-model-based case is studied, in which a T-S fuzzy model with norm-bounded uncertainties is used to describe the nonlinear AFTCS. Robust stochastic stability and stabilization conditions for the uncertain fuzzy system are provided in terms of LMIs. Finally, a simulation example is presented to illustrate the effectiveness of the proposed design method.*

Keywords: Fault tolerant control systems, Fuzzy control, Linear matrix inequality (LMI), Robust control, Stochastic stability, Takagi and Sugeno fuzzy model

1. Introduction.

In engineering systems, the component faults are inevitable and unpredictable. Their consequences can be disastrous for safety-critical systems, such as aircraft, space vehicles and nuclear plants. In order to achieve a high level of reliability, fault tolerant control (FTC) has attracted lots of attention during the last two decades. Numerous FTC design schemes have been developed [1-14], which can be broadly classified into two types: passive [1-5] and active [6-14]. A passive FTC system (PFTCS) utilizes a fixed gain controller to tolerate predefined faulty operations while maintaining satisfactory performance. An active FTC system (AFTCS) needs a fault detection and isolation (FDI) scheme [15,16] to identify the fault-induced changes, and a mechanism to on-line reconfigure the control law in response to the FDI decisions. Compared with PFTCSs, AFTCSs have in general better fault-tolerance capability, and hence are more desirable for practical applications.

The dynamic behavior of AFTCSs is governed by stochastic differential equations, due to the fact that the failures and FDI decisions occur randomly [15]. In [9], sufficient conditions for exponential stability in the mean square (ESMS) of linear AFTCSs with Markovian failure characteristic and random detection delays were derived. However, these results assume that a correct failure diagnosis is always made following a failure. To overcome this limitation, two Markov processes were separately introduced to model